NOAA Technical Memorandum NWS SR-80

MANUALLY DIGITIZED RADAR GRIDS: A COMPARISON OF RESOLUTION CAPABILITIES FOR A HEAVY RAINFALL SITUATION

James D. Belville
WSFO, Lubbock, Texas

Scientific Services Division
Southern Region
Fort Worth, Texas
February, 1975

AMERICAN REVOLUTION BICENTENNIAL 1776-1976

UNITED STATES DEPARTMENT OF COMMERCE
Frederick B. Dent, Secretary

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
Robert M. White, Administrator

National Weather Service
George P. Cressman, Director

NOAA
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
U.S. DEPARTMENT OF COMMERCE

MANUALLY DIGITIZED RADAR GRIDS: A COMPARISON OF RESOLUTION CAPABILITIES FOR A HEAVY RAINFALL SITUATION

INTRODUCTION

As communities expand and a larger percentage of the population moves into rural areas, encroachment into areas subject to flooding will increase. The National Weather Service (NWS) hydrologic and radar programs must improve techniques in accurately locating and quickly identifying heavy rainfall patterns to prevent loss of life.

One approach to this problem was the introduction of the Manually Digitized Radar (MDR) Program (Moore, Cummings and Smith, 1974). This particular type of system enables forecasters and hydrologists to keep track of rainfall patterns by using a quantitative index. However, because of the inherent ambiguity of MDR data, refinement of that system is necessary in order to increase its reliability.

In this paper, a higher resolution grid, ∿ 20 n mi (37 km) on a side, is used in an attempt to locate a rainfall pattern with more precision than is possible with the present system. Use of the smaller grid should also provide a better basis for estimating the magnitude of the rainfall in areas where rainfall data are sparse.

PROJECT STORM

The case examined in this study was the Pecos River Storm which occurred on September 19, 1974, in a remote area of Southwest Texas, centered near the town of Bakersfield (65 n mi [120 km] south of Midland, Texas). Rainfall at Bakersfield amounted to 15.50 in (394 mm) from 1300Z on the 18th to 1530Z on the 19th. However, the NWS cooperative observer at Bakersfield stated that nearly all of the precipitation fell between 000Z and 1530Z on the 19th, and even though the rains were heavy they fell at a relatively uniform rate. This is supported by the WSO Midland radar overlays. Therefore, the time frame of this study will be 19/0000Z to 19/1530Z.

The ensuing flood on the Pecos River was the second largest of this century, producing a crest of 22.15 ft (6.65 m) at Sheffield, Texas, with an estimated flow of 53,000 cfs (1500 cms). This would later cause a critical situation at Amistad Dam near Del Rio, Texas.

RADAR CHARACTERISTICS OF THE PRECIPITATION

The storm was at all times under surveillance of the Midland WSR-57, well within range of the radar.

In general, radar reports from Midland indicated heavy to very heavy echoes scattered over an area about 100 mi (183 km) wide extending from near Midland to about 40 mi (73 km) southwest of Bakersfield (Fig. 1), during the time covered by this study. The general area of precipitation moved very little during the night, but individual cells were moving from 190°-220° at 12-18 kts (22-33 km/hr) with an average speed of 15 kts (28 km/hr). Maximum tops of the cells were generally 35- to 40,000 ft (10,500-12,000m) but reached a maximum of 45,000 ft (13,500 m) at 0734Z, 10 mi (18.5 km) southwest of Bakersfield. The maximum intensity at any reporting time was a VIP 4 (indicating a rainfall rate of 1-2 in/hr [25-51 mm/hr]), which occurred on several occasions.

ANALYSIS OF STANDARD MDR SQUARES

The 16 one-hour MDR values were totalled for each square and plotted on a gridded overlay (Fig. 2). Relatively large totals are located in the second and third squares of the fourth row and in the second square of the fifth row. This corresponds well with the area of heavy rainfall as depicted by the isohyetal analysis in Fig. 3. However, the rainfall analysis indicates that a large portion of the total area of the three squares involved did not receive excessive rainfall. An hourly breakdown of MDR data is given in Fig. 4.

Referring to Fig. 4, the persistence of VIP levels 3 and 4 (MDR code numbers 4 and 6) in the two squares on the fourth row with large totals is quite pronounced. This is an indicator of the possibility of large rainfall amounts within these squares. However (see Fig. 5) the even code numbers reported indicate that echoes of intensity VIP 3 or greater covered no more than half of the square. The present grid size, therefore, results in ambiguity with respect to the exact location of the heavy rain.

ANALYSIS OF HIGHER RESOLUTION MDR SQUARES

The "standard" MDR squares were quartered in this study in order that a higher resolution grid be obtained. After this process was completed, MDR values were calculated (from the Midland WSO's original paper radar overlays) in the same manner as is done for the normal size grid, using the code in Fig. 5. For identification purposes, the rows in the higher resolution grid were assigned letter designators and the columns numbers. Also, in replotting the precipitation pattern on the small grid overlays, VIP 1 echoes were omitted unless accompanied by VIP 2 or higher.

The MDR totals based on the new grid for the 16 one-hour observations from 19/0000Z to 19/1530Z are plotted in Fig. 6. The highest totals for the time period are confined primarily to three squares: D4, D5 and E3. This also corresponds well with the isohyetal analysis in Fig. 7. Hourly values for the higher resolution MDR squares are shown in the digitized echo log in Fig. 8.

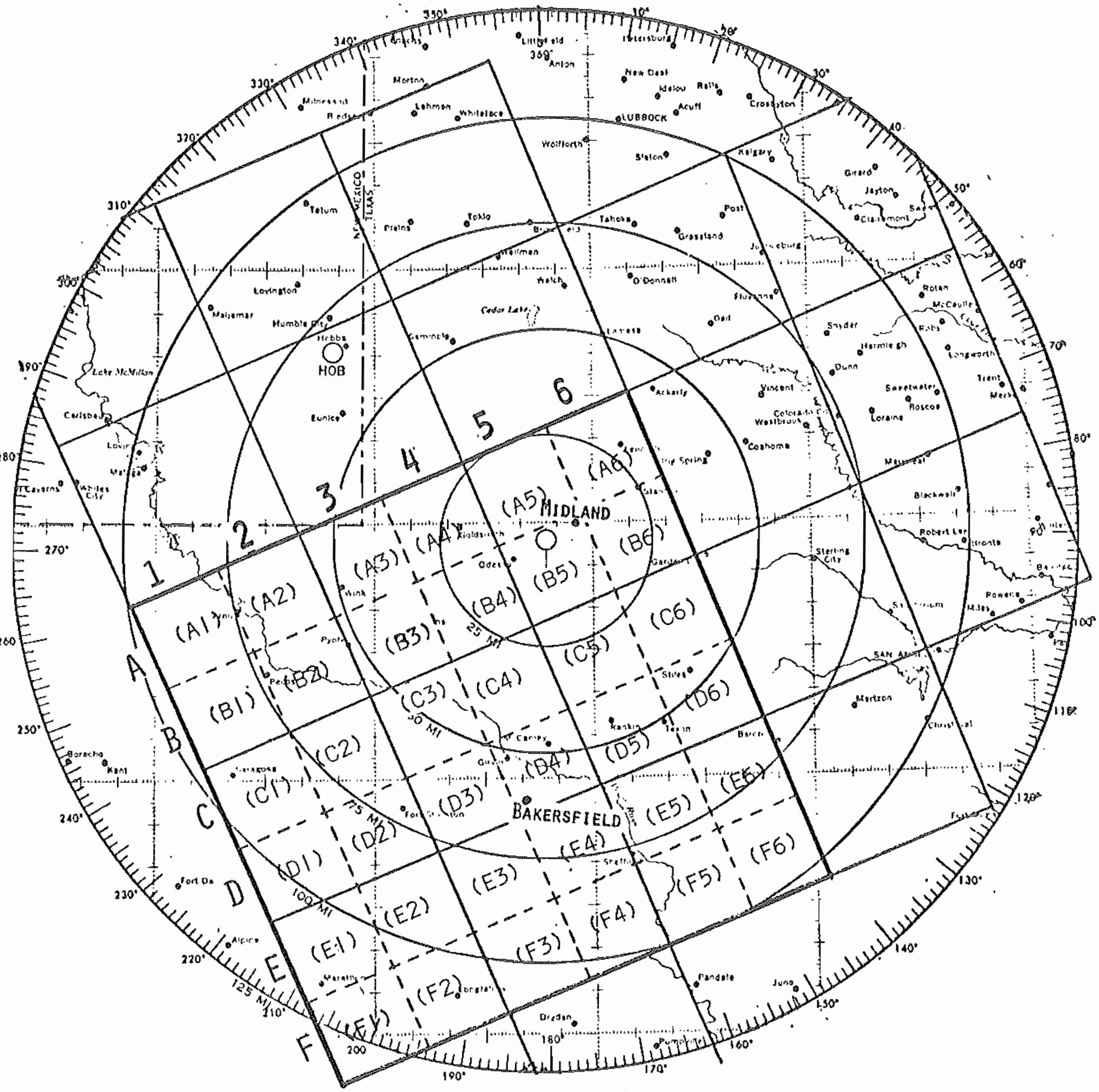

Fig. 1. MDR overlay for WSR-57 at WSO, Midland, Texas delineating area of study. Letter and number designators for higher resolution grid are in parenthesis.

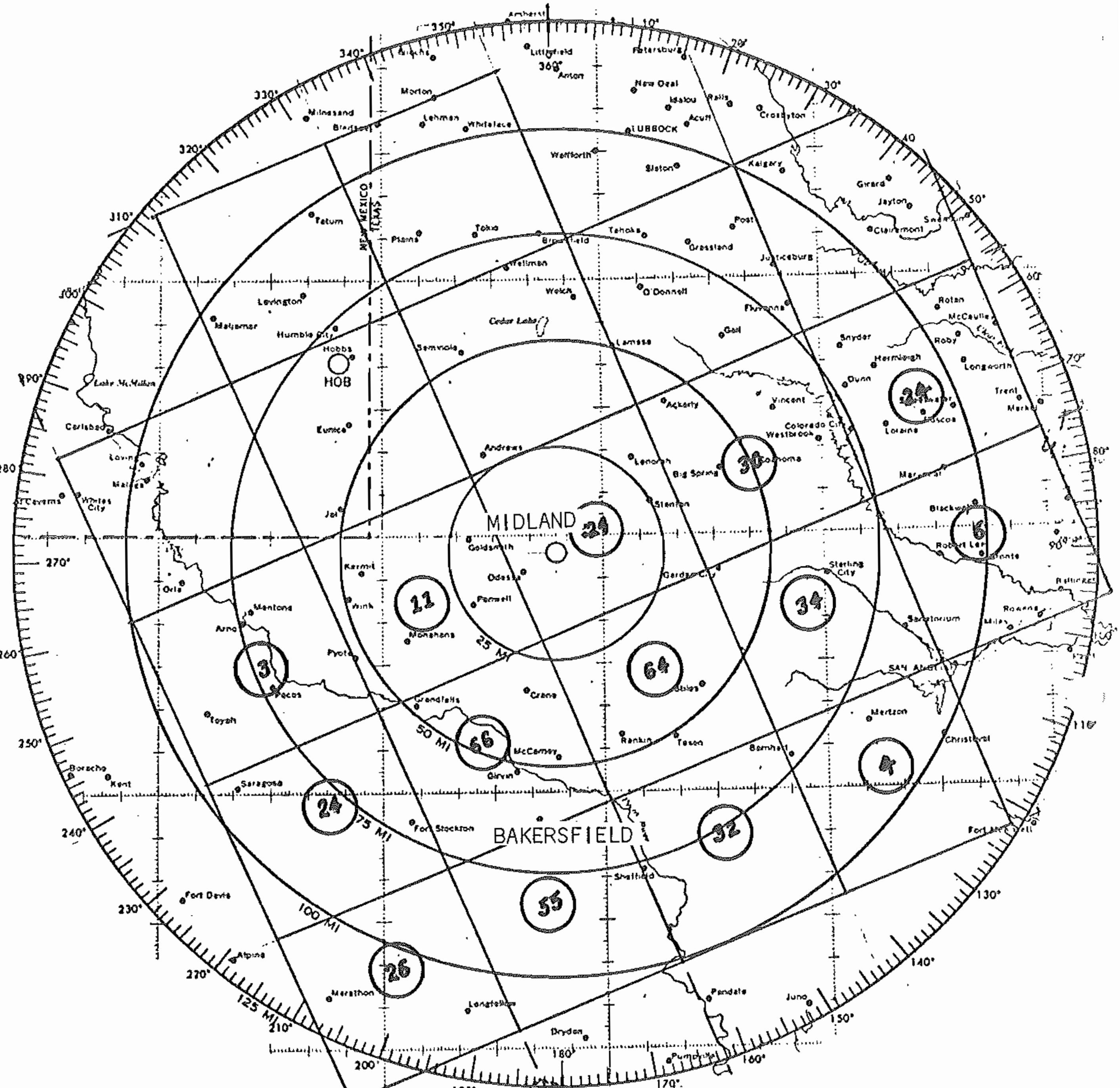

Fig. 2. Totals for the standard MDR grid of WSR-57 at WSO, Midland, Texas from 19/0000Z to 19/1530Z.

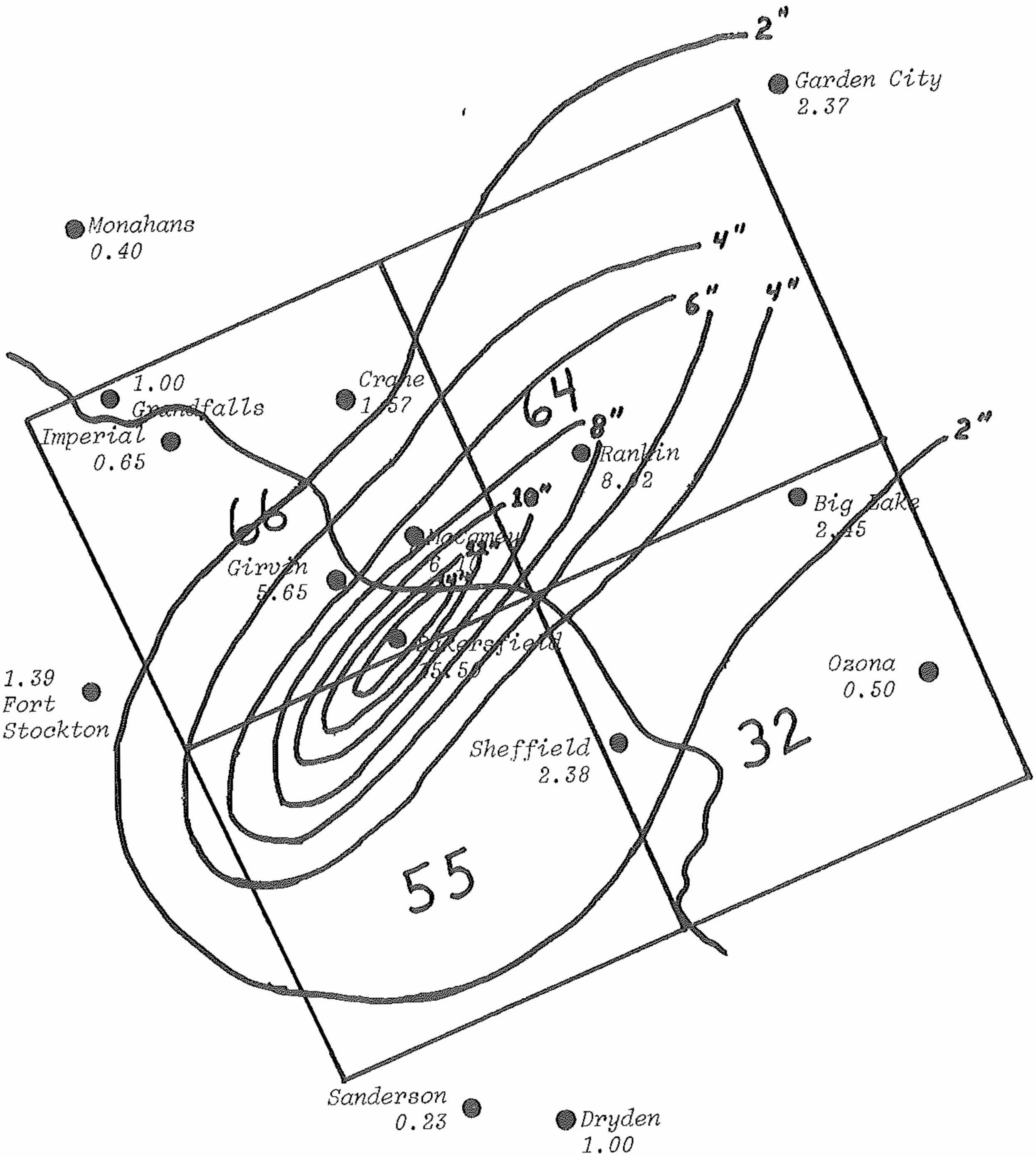

Fig. 3. Isohyetal analysis of the Pecos River Storm superimposed on the standard MDR grid. MDR totals are for time period 19/0000Z to 19/1530Z.

GMT	ROW 3					ROW 4					ROW 5			
	1	2	3	4	5	1	2	3	4	5	1	2	3	4
0030	0	2	1	1	1	1	4	2	2	0	2	2	0	1
0130	0	1	2	1	2	0	4	2	2	2	2	4	0	2
0230	0	0	2	2	2	1	4	4	4	2	6	2	0	0
0330	0	1	1	2	1	1	4	4	4	1	2	4	0	0
0430	0	0	2	4	2	1	4	4	2	1	1	4	0	0
0532	1	1	4	4	4	1	4	4	4	0	2	6	4	0
0630	1	1	1	4	2	2	2	6	1	0	4	6	6	0
0734	0	0	2	1	1	2	4	4	1	0	2	6	4	0
0830	0	0	1	1	2	4	6	6	2	0	1	4	4	0
0934	1	1	1	2	0	4	4	4	2	0	2	2	4	0
1032	0	1	1	2	1	2	6	6	2	0	1	2	4	0
1133	0	1	1	1	1	2	4	4	2	0	0	1	2	0
1230	0	1	1	2	2	1	4	4	2	0	0	2	1	0
1332	0	0	1	1	1	0	4	2	2	0	1	4	1	1
1430	0	0	2	1	1	1	4	4	1	0	0	4	1	0
1531	0	1	1	1	1	1	4	4	1	0	0	2	1	0
TOTAL	3	11	24	30	24	24	66	64	34	6	26	55	32	4

Fig. 4. Digitized Echo Log for WSR-57 at Midland, Texas for the standard MDR grid. Time period September 19/0000Z to 19/1530Z.

CODE NO.	COVERAGE	INTENSITY	RAINFALL RATE (in/hr.)
1	Any VIP 1	Light	.1
2	≤ 1/2 of VIP 2	Moderate	.1-.5
3	> 1/2 of VIP 2		
4	≤ 1/2 of VIP 3	Heavy	.5-1
5	> 1/2 of VIP 3		
6	≤ 1/2 of VIP 3 & 4	Very Heavy	1-2
7	> 1/2 of VIP 3 & 4		
8	≤ 1/2 of VIP 3,4,5,6	Intense	2
9	> 1/2 of VIP 3,4,5,6		

Fig. 5. Manually Digitized Radar (MDR) Code.

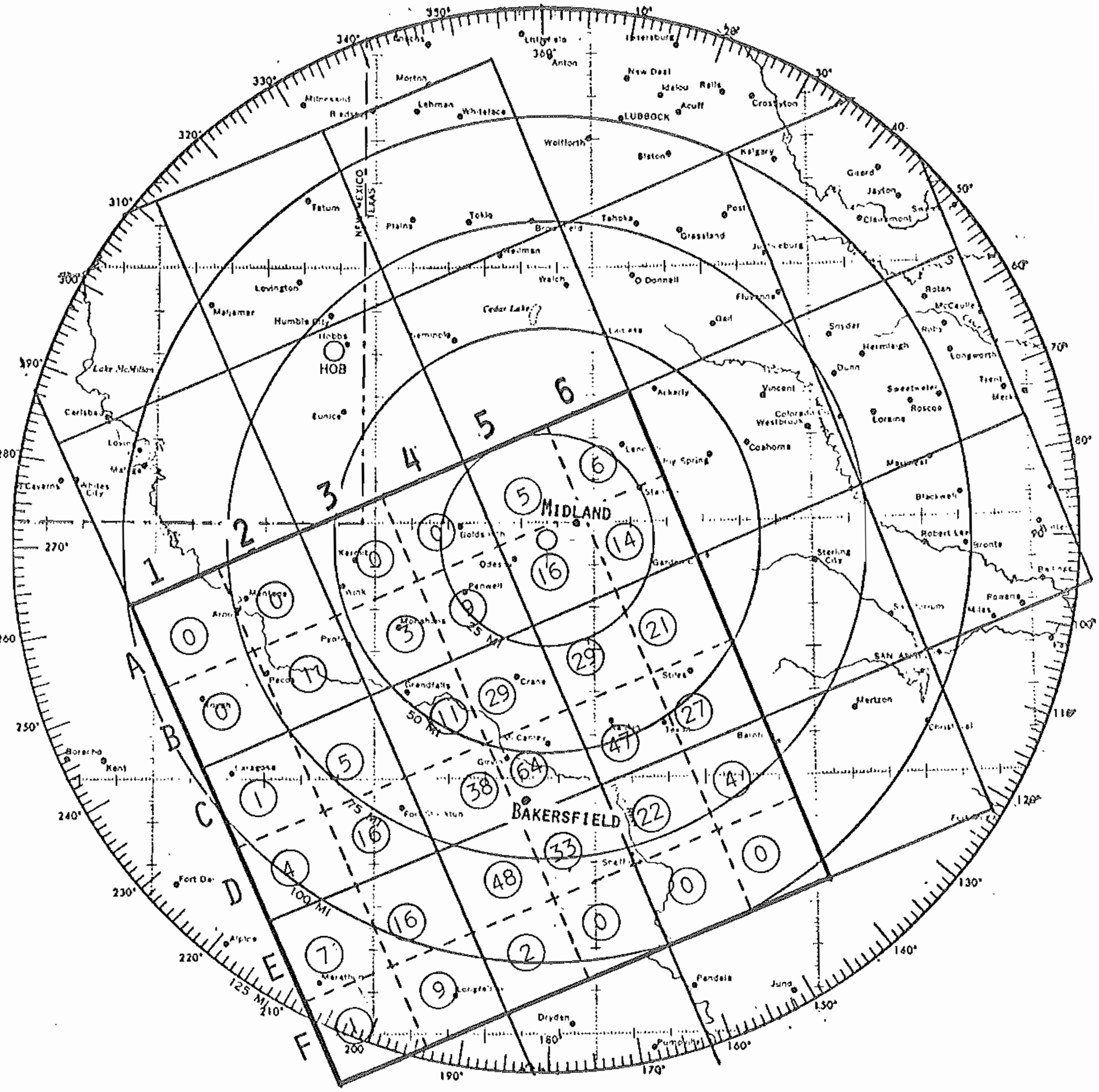

Fig. 6. Totals for the higher resolution MDR grid from 19/0000Z to 19/1530Z.

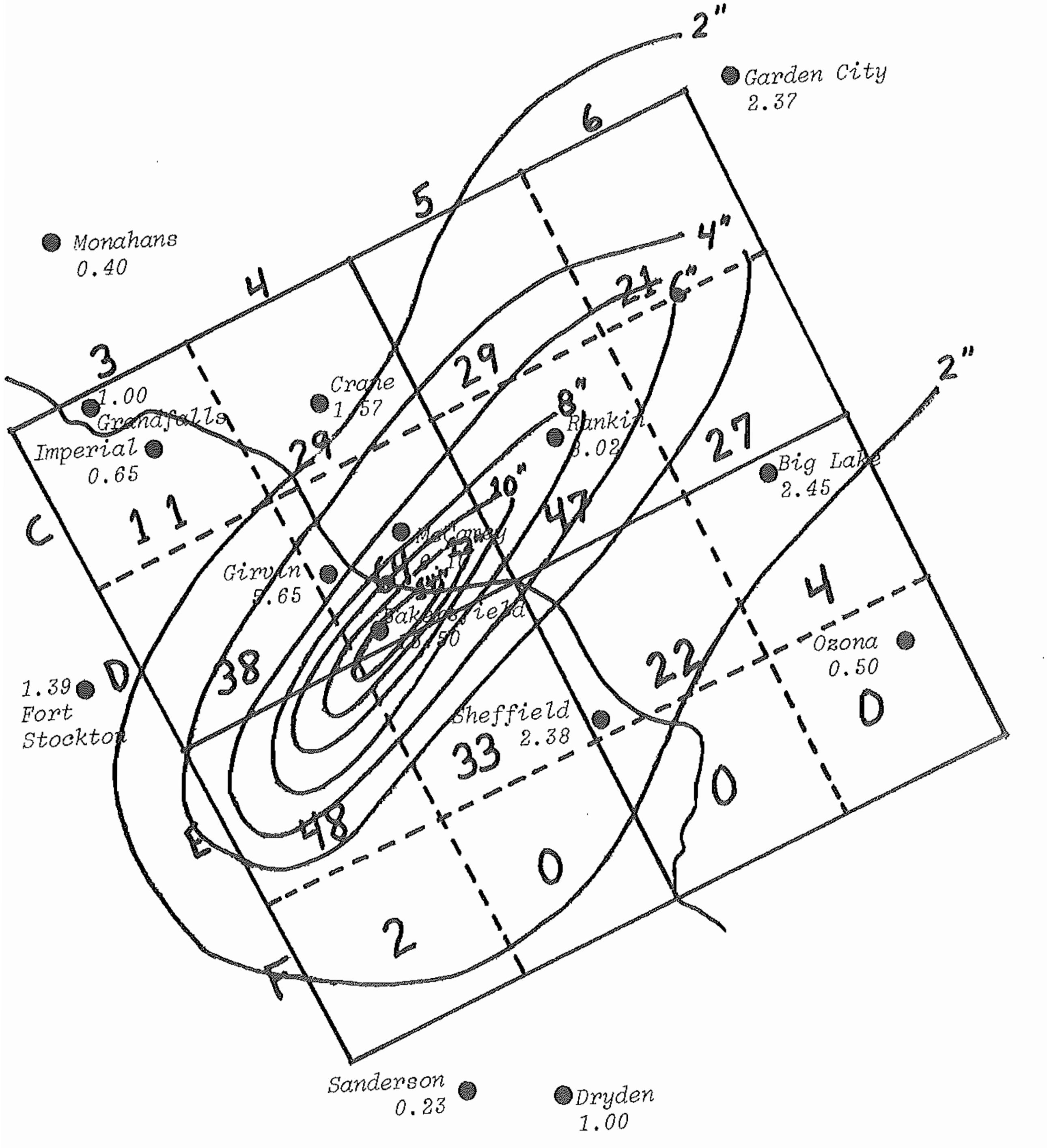

Fig. 7. Isohyetal analysis of the Pecos River Storm superimposed on the higher resolution MDR grid. MDR totals are for time period 19/0000Z to 19/1530Z.

GMT	00Z	01Z	02Z	03Z	04Z	05Z	06Z	07Z	08Z	09Z	10Z	11Z	12Z	13Z	14Z	15Z
A1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A5	0	0	0	0	0	1	0	0	0	0	1	1	2	0	0	0
A6	0	0	0	1	2	0	1	0	1	0	1	1	1	0	1	0
B1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
B3	0	0	0	0	0	1	0	0	0	1	1	0	0	0	0	0
B4	0	1	0	1	1	1	1	0	1	0	1	1	1	0	0	0
B5	0	2	1	1	1	1	1	2	1	1	1	1	2	0	1	0
B6	0	0	0	1	1	1	1	2	1	1	1	1	2	0	2	0
C1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
C2	0	0	0	0	0	0	0	1	2	2	0	0	0	0	0	0
C3	2	0	0	1	1	1	0	1	0	2	1	1	1	0	0	0
C4	2	4	2	1	1	2	1	2	1	1	6	1	2	1	1	1
C5	0	0	4	4	1	2	4	2	2	1	2	2	1	1	2	1
C6	0	0	0	0	0	2	4	2	2	2	2	2	2	1	2	0
D1	0	0	0	0	0	0	1	2	1	0	0	0	0	0	0	0
D2	1	0	0	1	1	0	0	1	4	4	2	2	0	0	0	0
D3	4	2	2	1	1	2	1	4	6	4	2	2	4	2	0	1
D4	4	2	4	4	4	4	2	4	6	4	6	4	4	4	4	4
D5	0	0	2	0	4	4	6	4	6	2	1	4	4	2	4	4
D6	0	0	0	0	0	1	2	4	4	4	2	2	4	2	2	0
E1	0	0	0	0	0	0	2	2	1	2	0	0	0	0	0	0
E2	1	0	2	2	1	2	4	1	0	2	1	0	0	0	0	0
E3	1	4	4	4	4	2	6	6	6	2	0	2	2	4	0	1
E4	0	0	4	1	4	6	6	2	1	0	1	1	0	4	2	1
E5	0	0	0	0	0	2	6	2	1	4	4	1	1	1	0	0
E6	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
F1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
F2	0	0	6	1	0	2	0	0	0	0	0	0	0	0	0	0
F3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
F4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
F5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
F6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fig. 8. Digitized Echo Log for higher resolution MDR grid. Time for observations is approximately H+30. Box identifiers are located in extreme left hand column.

Again, as noted in the analysis of the standard MDR data, VIP 3 and 4 echoes were quite persistent within the squares containing the heaviest precipitation. This was especially true for square 4D.

COMPARISON OF THE TWO SYSTEMS

Comparing Fig. 3 and Fig. 7, it can be seen that the heaviest rainfall was confined to three of the small squares, or a total of 1200 sq mi (4100 sq km). The three large squares which included the heaviest amounts comprised an area of 4800 sq mi (16,400 sq km) or at least four times the actual rainfall area. Until a fully automated system is available, the length of the messages to be transmitted and the observer workload in coding more blocks must be balanced against the desirability of optimum resolution. It is evident, however, that definition of the precipitation pattern in this case was greatly improved with the higher-resolution grid.

DETECTING HEAVY RAINFALL BY PERSISTENCE USING THE HIGHER-RESOLUTION GRID

The main objectives in using MDR data are to gain an idea of the areal coverage and duration of precipitation within a certain area and put the data in the form of a quantitative index. This, in fact, is the only method which could be used in identifying the Pecos River Storm, due to the sparse data network. Because of communications problems rainfall reports indicating the extreme precipitation amounts were not received by WSFO Lubbock until some twelve hours after the beginning of the storm. These were from Rankin (8.02 in [204 mm]) and McCamey (6.70 in [170 mm]). The report of 15.50 in (394 mm) at Bakersfield was obtained even later. Using the higher resolution grid, the persistence of heavy precipitation is quite pronounced and easily identifiable, as can be seen from the data listed in Fig. 8. A six-hour total of 24 appears to be a good threshold for indication of heavy rains since that total would indicate an average hourly value of MDR 4 (heavy intensity). In analyzing the cumulative MDR values, the only squares which had six-hour totals of 24 were those in which heavy rains were reported. The square in which persistence was best demonstrated was D4 (which contains Bakersfield). Study of the fifteen-hour period for all squares revealed thirteen six-hour periods in which MDR values totalled 24 or greater; Square D4 had eight of those thirteen cases. Actually, that square had a value of MDR $\geq$ 4 for more than half the period. This is quite significant considering the size of the small squares.

CONCLUSIONS

It is evident from comparisons in the preceding sections that increasing the resolution by a factor of two, as is done with the smaller grid, significantly improves the reliability of the system. The storm used as an example shows this quite clearly because it was located near the intersection of large squares; the smaller grid helped to remove some of the uncertainities, as can be seen by comparing Fig. 3 and Fig. 7. It is realized that quartering the present squares would increase the workload. However, there are ways a reduced grid size could be used without drastically increasing the observer time or communications load.* One approach would be to quarter the regular squares after the MDR values indicate the possibility of heavy rains and re-evaluate the data using the small squares to detect the persistence of echoes within a certain area of the "standard" (large) MDR square. Another would be to quarter the squares in which a particular flood-prone area is situated. Indications are that use of a higher-resolution grid would be quite valuable. However, it should be used in the same manner as the standard MDR system, i.e., careful consideration should be given to the existing meteorological conditions and all other available information.

*(Editor's Note: NWS Headquarters is considering a change in the MDR program whereby much more comprehensive data would be encoded in digital form, replacing the present "SD" or azimuth-range type of report. Eliminating the present dual reporting system would help to relieve problems of workload and communications. It is likely that the grid size would approximate the one proposed in this paper.)

ACKNOWLEDGEMENTS

The author wishes to thank Paul Moore and Dan Smith, Scientific Services Division, National Weather Service Southern Region Headquarters, and Young T. Sloan, MIC, WSFO Lubbock for their encouragement and assistance in writing this paper. Thanks are also due the staff of WSO Midland for the excellent radar data they provided for use in this study.

REFERENCE

Moore, Paul L., Allen D. Cummings, and Daniel L. Smith, 1974: The National Weather Service Manually Digitized Radar Program and Some Applications. NOAA Technical Memorandum NWS SR-75, 21 pp.